Evaluation of a

COMMERCIAL CONTINUOUS INHALABLE PARTICULATE MONITOR

(MDA Scientific BAM-102)

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August 1989 - PMD 89-24

1. DESCRIPTION of the INSTRUMENT

The MDA model BAM-102 beta attenuation mass monitor was received completely assembled. The instrument was contained inside an ABS enclosure with cooling vents; a weather seal was used around the cabinet door. The air flow pump was mounted in a smaller weather proof enclosure directly below the main instrument cabinet. The 10 micron inlet was mounted directly on top of the main instrument cabinet. An external water trap was connected to the side of the inlet stem. The whole instrument was mounted on a steel rack designed to facilitate exterior installation.

The main cabinet door opened to expose the complete front panel of the instrument. On the front panel were the sampling tape transport system, the control keyboard and the data print out system.

A summary of the unit's specifications are given in *Table 1.*

Measurement Cycle

The measurement cycle of the instrument consists of the following steps (see *Figure 1*):

1. The measurement probe takes a reading of the radiation passing through a spot on the clean filter tape.

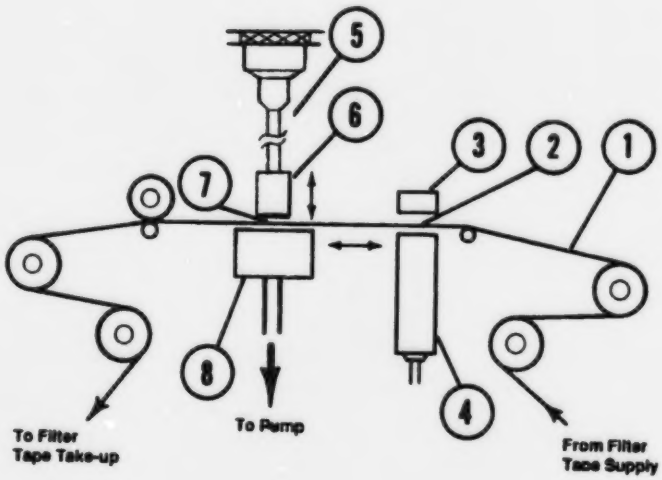
2. The spot is advanced to the sample collection point. The 10 micron particles in the air stream are deposited on the filter tape.

3. After a predetermined sampling period, the filter tape backs up to the measurement position where a second reading is taken on the spot where the dust particles are deposited.

TABLE 1 - SPECIFICATIONS for BAM-102 BETA GAUGE ATTENUATION MONITOR (Manufacturer)

Measurement Range	0 - 10 mg/m^3
Resolution	±0.010 mg/m^3 (1 hour mode)
Accuracy	Airborne Particles ±10% of indication Reference Membrane: ±3%
Beta Ray Source	C_{14} (sealed) Intensity: <100 µCi Half Life: 5730 years
Detector	Plastic scintillation probe
Flowrate	16.7 litres/min for Andersen 10 µm inlet head
Filter Paper	Material: glass fibre (Millipore AP-2) Efficiency: >99.9% (for DOP 0.3 µm)
Single Output	0-1, 2, 5 or 10 volt; 4-20 mA or RS-422
Relay Output	Power failure, conc. range, data error, pulse output, filter paper storage
Power Consumption	Main Unit = 75 VA Pump = 160 VA
Dimensions	495(D) x 475(W) x 1235(H) mm
Weight	80 Kg (without external enclosure)

FIGURE 1 - MEASUREMENT CYCLE for BAM-102 BETA GAUGE SAMPLER



1-Filter Paper Tape
2-Measuring Position
3-C_{14} Source
4-Plastic Scintillation Probe
5-Inlet
6-Air Sampling Nozzle
7-Dust Collection Point
8-Sampling Head

4. The difference between the two beta radiation readings is used to calculate the dust particle concentration in the air sample. The result is indicated in the print out as well as stored in memory for further data reduction as required.

5. The tape is then advanced to the next measurement cycle.

Control Panel

The controls of the instrument are located below the tape drive mechanism in the main instrument cabinet. They consists of a light group for indicating operational errors, such as low or high flow situations, calibration faults, beta count instability, telemetry faults and tape problems. There is a digital display for the indication of flow rate and beta count rate. Control is also provided for printer feed and printer on and off. The sampling nozzle can be lifted from or clamped onto the sampling tape manually. Controls for the interaction with the telemetry system are also found in this panel. The instrument can be set to either standby mode, measurement mode or calibration mode through the control panel. The filter tape can be advanced manually while the instrument is in the standby mode. The date and time in the instrument memory can also be entered through the keyboard panel.

Data Reporting

The BAM-102 can report data in daily printout or in telemetry mode. The telemetry mode was not tested in this evaluation. The printout mode reports starting time and date, hourly mass measurement and the hour of the measurement. At the end of the day, it prints out a summary of the measurement of the day giving the average concentration, the maximum and minimum concentration as well as the number of data points taken. An automatic calibration is also given and the difference from the original calibration is printed.

Calibration

The calibration of the instrument is effected by taking a reading with the detector while a plastic reference membrane is inserted under the measurement head to simulate a dust deposit. This reading is compared with the reading without the reference membrane in place. The results of the calibration are printed with date and time attached. The complete calibration routine requires about five minutes and is simply activated by the calibration entry on the key board.

Flow Rate

The sampling flow rate is adjusted by turning a potentiometer on the control panel. The flow rate is displayed by the digital readout on the control panel.

2. OPERATIONAL IMPRESSIONS

Since the instrument was available only for a limited length of time, no detailed operational evaluation was performed on the unit. The instrument was unpacked and checked for shipping damages upon arrival. The sampling filter tape was installed. All operational functions of the unit were verified to function and the unit was left running in the laboratory for a period of 10 days while sampling room air.

During this laboratory operating period the frequency count of the detector was stable. The flow rate was stable at 16.7 lpm. The tape transport mechanism operated without problem. One power interuption occurred during this time period; this was correctly recorded by the instrument and the sampling continued without interruption. Installation and removal of the tape was straight-forward.

Noise level of the instrument was low. This was probably due to the pump being completely enclosed in the weather proof cabinet. A higher pump noise level will be expected for interior installation with the pump cabinet removed.

After the laboratory checkout was completed, the instrument was installed on the roof of an air monitoring station. The unit was cumbersome to transport when completely assembled since the weight was in excess of one hundred kilograms. The unit was lifted onto the roof by a crane.

During the entire field testing period, no breakdowns were encountered. On one occasion the printer paper jammed; this was probably caused by misalignment on the paper when tearing it off.

From an operational point of view the instrument did not require any undue attention for the time period in which it was tested. The tape transport system appeared well designed. The printer paper refill tray was easily accessible and the printout was legible.

3. FIELD EVALUATION

3.1 General

The BAM-102 unit was installed on the rooftop of an air monitoring station located at Rideau and Wurtemburg Streets in downtown Ottawa. The unit was placed in the field on January 18, 1989 and operated until April 11, 1989, a total of 84 days. Also located at this station were a Sierra-Andersen dichotomous sampler equipped with 10 µm inlet head and a Sierra-Andersen size selective hi-vol (SSI) equipped with a Model 1200 10µm inlet. Both of these PM_{10} samplers were operated in conformance with National Air Pollution Surveillance (NAPS) quality assurance practices. Flow audits of the samplers were carried out at the completion of the field study.

The BAM-102 unit operated without any significant problems during its time in the field. The mean temperature during the field evaluation at Ottawa was -7.5°C : there were 12 days with minimum temperatures lower than -20°C (period minimum of -27.2°C). The average daily maximum relative humidity was 80%: there were 20 days with maximum humidity greater than 90%.

3.2 Comparison of BAM-102 PM $_{10}$ and Manual Sampler

The dichotomous sampler and the SSI hi-vol sampler were operated for 24 hour periods on an approximate three day sampling schedule. There were a total of 23 days with BAM and dichotomous sampler data; 23 days with BAM and SSI data and 21 days with BAM, SSI and dichotomous sampler data. All collected 24h data is provided in *Table A1* of *Appendix A.* In *Table 2* a summary of mean PM_{10} concentrations for SSI and dichotomous sampler sampling days and mean differences between samplers is provided. A paired t-test showed that the mean PM_{10} concentration measured by the BAM-102 unit was significantly different than that measured by the SSI hi-vol (P=0.99) but not significantly different than that measured by the dichotomous sampler. The difference between the BAM-102 PM_{10} value and the SSI and dichotomous sampler PM_{10} value was largest on April 4 (BAM approximately 100% higher). If this value is excluded as an outlier the mean difference between the BAM and the dichotomous sampler was 2.5 µg/m3 (+9%) and the mean difference between the BAM and the SSI was 4.3 µg/m3 (+16%). The BAM 102 generally read higher than either the dichotomous or SSI sampler PM_{10}.

A plot of SSI and Dichotomous sampler PM_{10} concentrations (independent variable) vs. BAM PM_{10} concentrations is given in *Figure 2.* *Table 3* provides slopes, intercepts and correlation coefficients for the best fit linear equations for BAM vs. dichotomous sampler PM_{10} and BAM vs SSI PM_{10}. The April 4 data were excluded from the calculations. Slopes for both equations was less than one; the intercept for the BAM-Dich equation was significantly greater than zero. In general there was less scatter in the BAM-SSI plot as shown by the higher correlation coefficient. Both the dichotomous sampler and the SSI hi-vol were highly correlated with the BAM. The correlation between the dichotomous sampler and the SSI were similar to that calculated for the BAM-SSI and the BAM-dichotomous sampler.

Figure 2: SSI & DICH PM10 vs Beta Gauge PM10 (24 h avg.)
Ottawa : Jan - Apr 1989

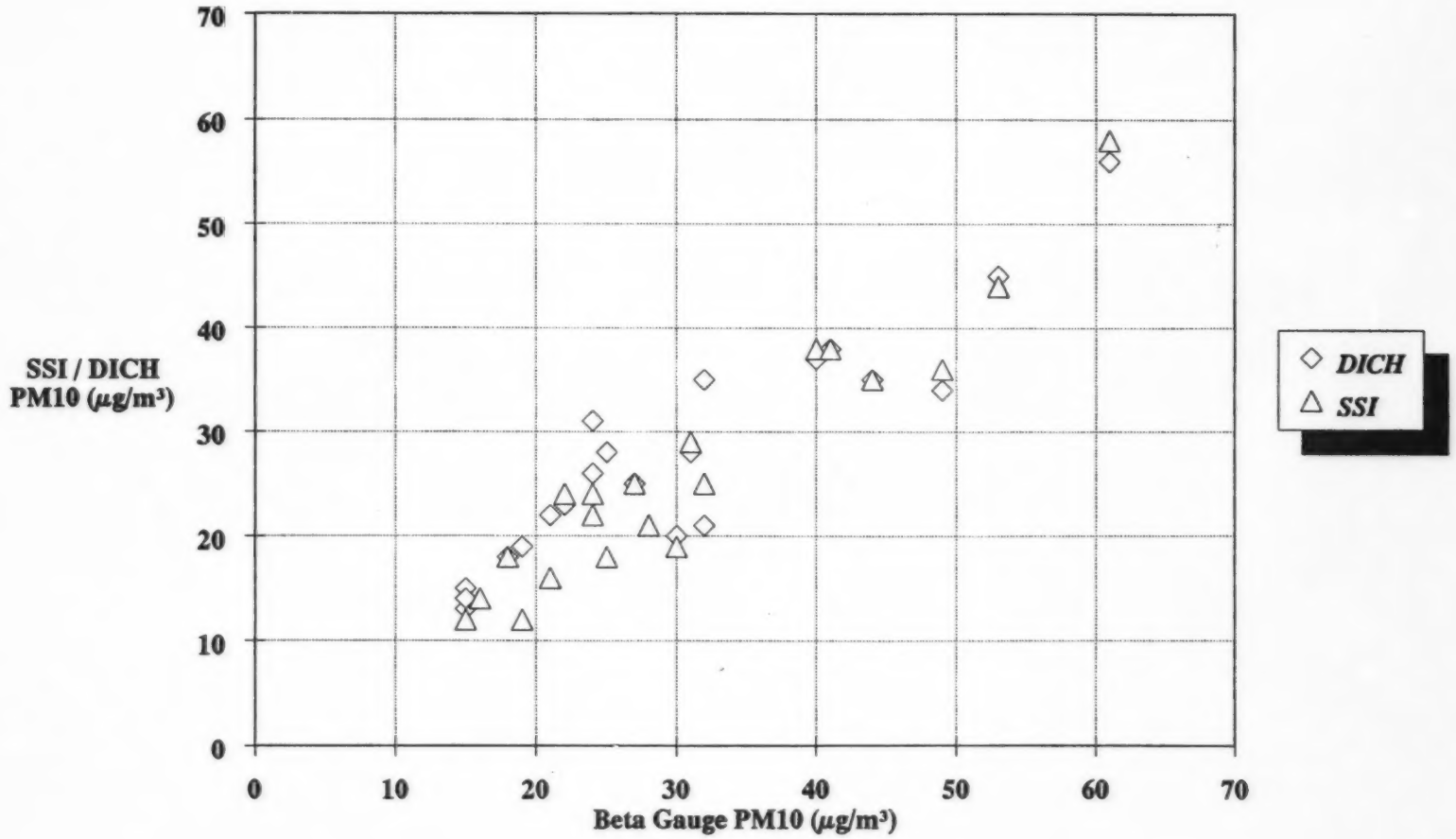


TABLE 2 - COMPARISON of BAM-102, DICHOTOMOUS SAMPLER and SSI HI-VOL PM_{10} CONCENTRATIONS (24h)

Date	Concentration (µg/m³)			Difference (µg/m³)		
	Dich	SSI	BAM	BAM-Dich	BAM-SSI	Dich-SSI
22-Jan-89		21	28		7	
24-Jan-89	35	35	44	9	9	0
28-Jan-89	35	25	32	-3	7	10
31-Jan-89	28	18	25	-3	7	10
3-Feb-89	14	12	15	1	3	2
7-Feb-89	26	24	24	-2	0	2
9-Feb-89	23	24	22	-1	-2	-1
10-Feb-89	21		32	11		
15-Feb-89	28	29	31	3	2	-1
18-Feb-89	25	25	27	2	2	0
21-Feb-89	34	36	49	15	13	-2
23-Feb-89	18	18	18	0	0	0
27-Feb-89	37	38	40	3	2	-1
2-Mar-89	18	18	18	0	0	0
5-Mar-89	13	12	15	2	3	1
7-Mar-89	31	22	24	-7	2	9
11-Mar-89	45	44	53	8	9	1
14-Mar-89	56	58	61	5	3	-2
17-Mar-89	19	12	19	0	7	7
21-Mar-89	22	16	21	-1	5	6
23-Mar-89	38	38	41	3	3	0
29-Mar-89	15		15	0		
4-Apr-89	27	29	55	28	26	-2
6-Apr-89	20	19	30	10	11	1
10-Apr-89		14	16		2	
Mean	27	26	30			

Mean Difference (µg/m³)	3.61	5.26	1.90
Std. Dev. of Difference	7.41	5.93	3.97
N	23	23	21
S_d	1.55	1.24	0.87
t_{EXP}	2.33	4.26	2.20
$t_{0.01}$	2.85	2.80	2.86

TABLE 3 - BAM-102 PM_{10} vs DICHOTOMOUS SAMPLER and SSI HI-VOL PM_{10} (24h averages)

Pair	No. of Days	Slope	Intercept	Correlation Coeficient (r)
BAM-Dich	23	0.765	4.4	0.855
BAM-SSI	23	0.866	-0.3	0.912
SSI-Dich	21	1.050	-3.4	0.890

An advantage of a continuous particulate monitor such as the BAM-102 unit is the generation of a greatly expanded PM_{10} data base, including hourly and daily values. Diurnal PM_{10} concentration variations can be examined and individual episodes highlighted. Manual PM_{10} samplers normally operate on a 3 or 6 day measurement cycle. In *Table 4* frequency distributions of PM_{10} calculated using BAM-102, SSI, and dichotomous sampler data are given. Because more high concentration days were included in the BAM data set, the apparent maximum, 98th and 90th percentile values were higher for the three month sampling period if BAM data were used rather than SSI or dichotomous sampler data.

TABLE 4 - FREQUENCY DISTRIBUTION of PM_{10} CONCENTRATIONS ($\mu g/m^3$)

	no. of samples	Max.	Percentiles		
			98%	90%	70%
BAM	80	70	67	53	33
Dich	24	56	56	38	31
SSI	24	58	58	38	29

3.3 Comparison of Coefficient of Haze (COH) and BAM-102 Measurements

In many provincial monitoring networks COH monitors are used as a surrogate for TSP or PM_{10} for purposes of reporting hourly real time index

values. The Federal Provincial Advisory Committee on Air Quality (FPACAQ) has recently recommended that COH monitors be used as a surrogate for inhalable particulates (PM_{10}) for purposes of index reporting.

At the Ottawa site a COH monitor was operated during the period of the BAM-102 evaluation. Hourly COH data was telemetered to the provincial environment ministry in Toronto; the data was later provided to Environment Canada.

Figures 3 to 7 provide plots of BAM PM_{10} vs. COH for three time periods: January, February and March-April. In *Table 5* slopes, intercepts and correlation coefficients are provided for the linear equation, PM_{10} (BAM) = a (COH) + b for each time period. It is apparent that there is a lot of scatter in the BAM/COH relationship although correlations were reasonably good. The large change in slope for different months reflects the fact that COH is not a mass related measurement but rather is based on the optical characteristics of the particles being sampled. As shown at the Ottawa site, COH/IP relationship will vary greatly depending on the nature of the particulate being measured and can be expected to change by season and with each change in dominant source. No site specific COH/IP relationship would be possible unless a site is affected only by one source at all times.

TABLE 5 - BAM-102 PM_{10} vs COH (1h DATA)

Month	No. of Values	Slope	Intercept	Correlation Coefficient (r)
Jan.	294	39.0	7.1	0.888
Feb.	435	66.9	5.2	0.823
Mar.	742	91.4	5.1	0.840
April	261	76.0	9.0	0.762
All	**1732**	**50.4**	**12.5**	**0.724**

Figure 3 : Beta Gauge vs COH - January 1989

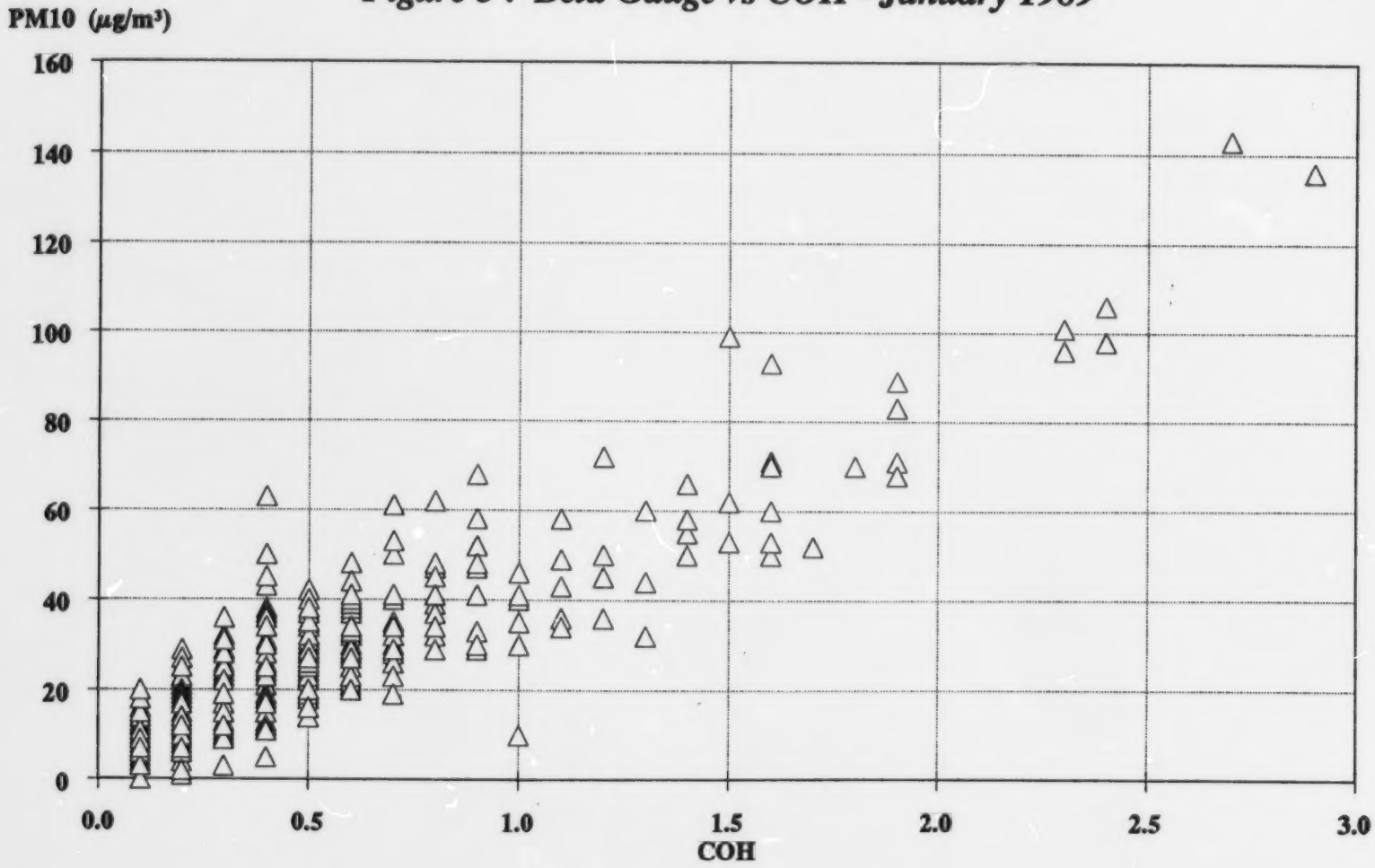


Figure 4 : Beta Gauge vs COH - February 1989

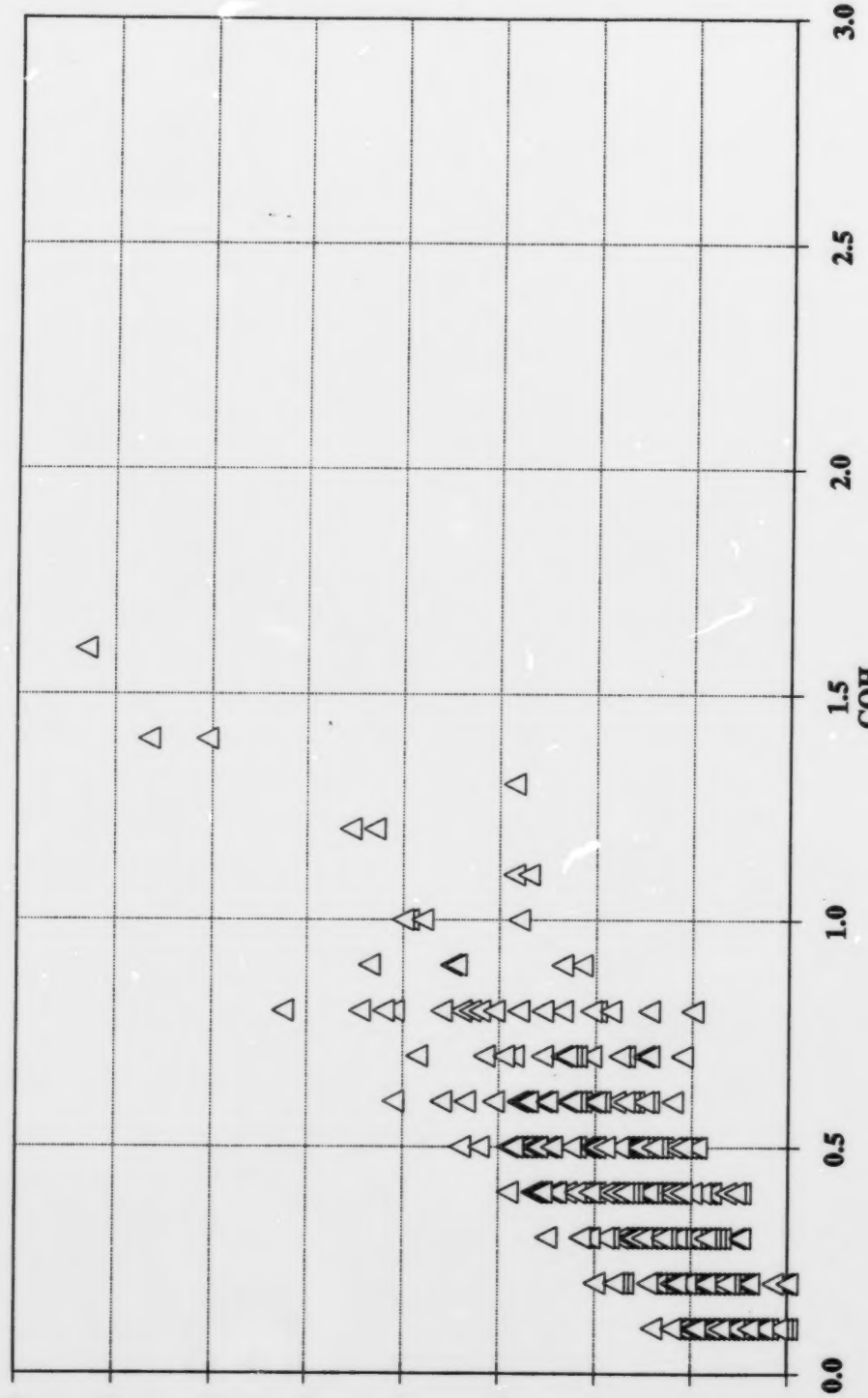


Figure 5 : Beta Gauge vs COH - March 1989

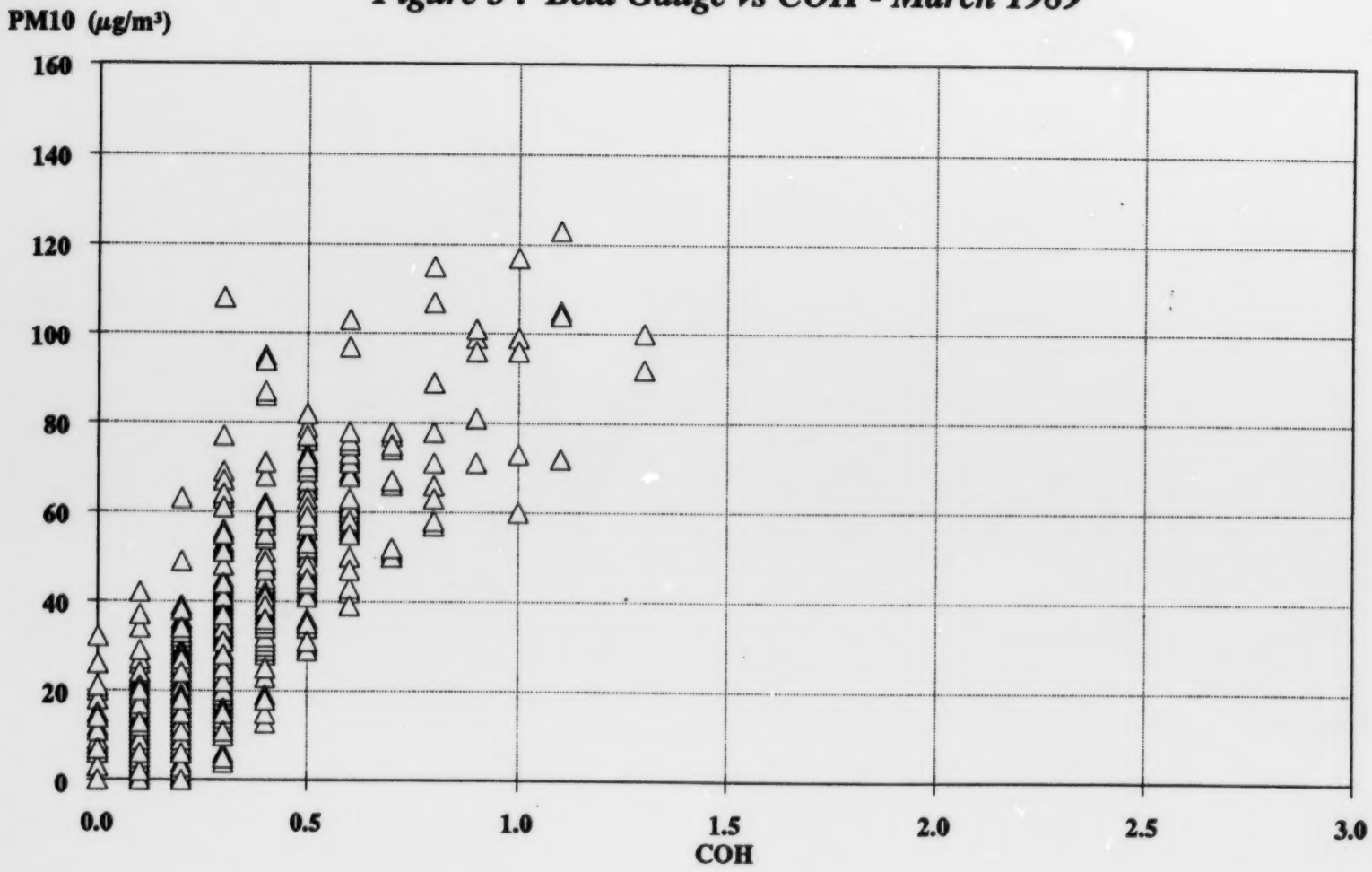


Figure 6 : Beta Gauge vs COH - April 1989

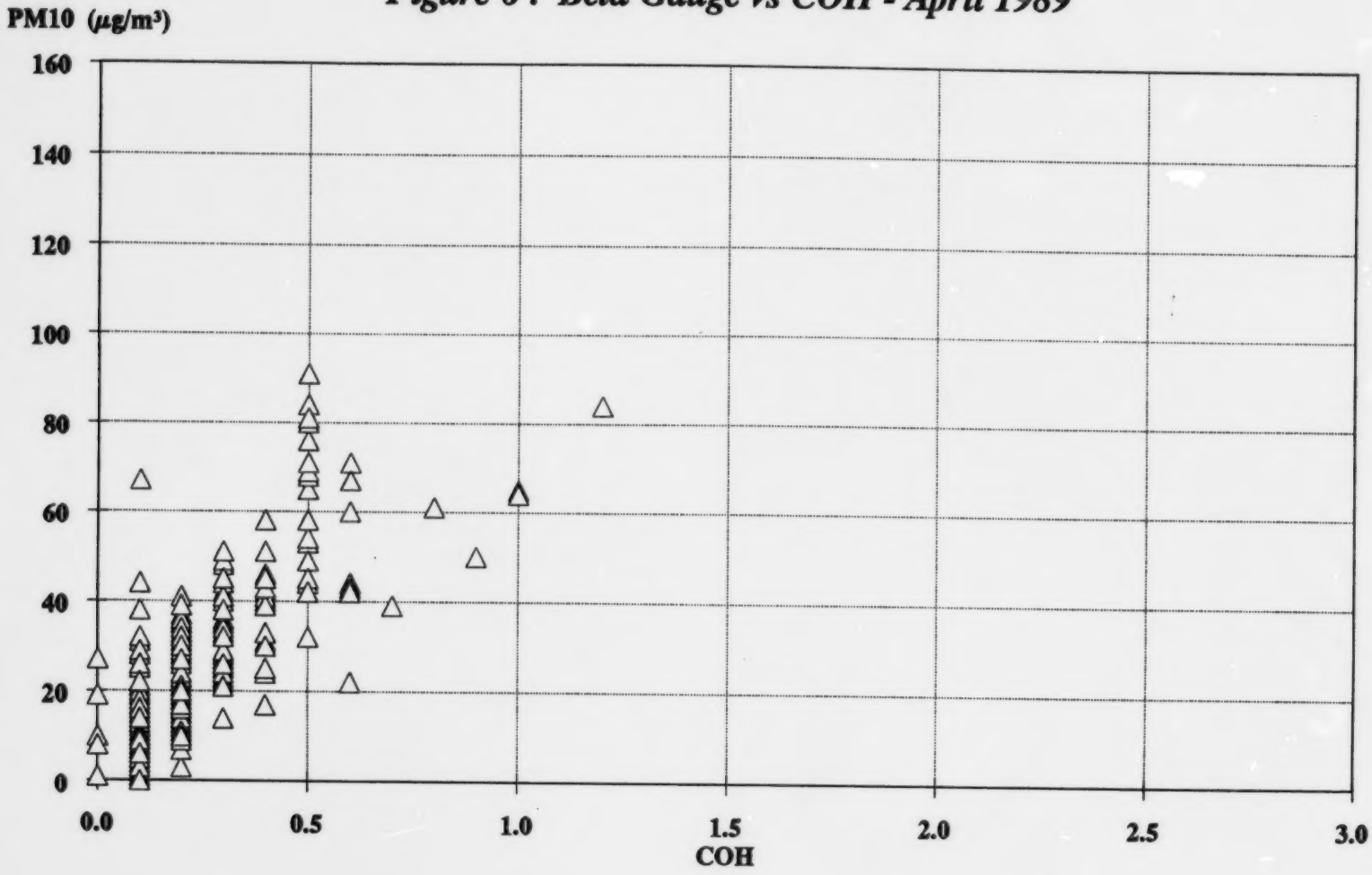
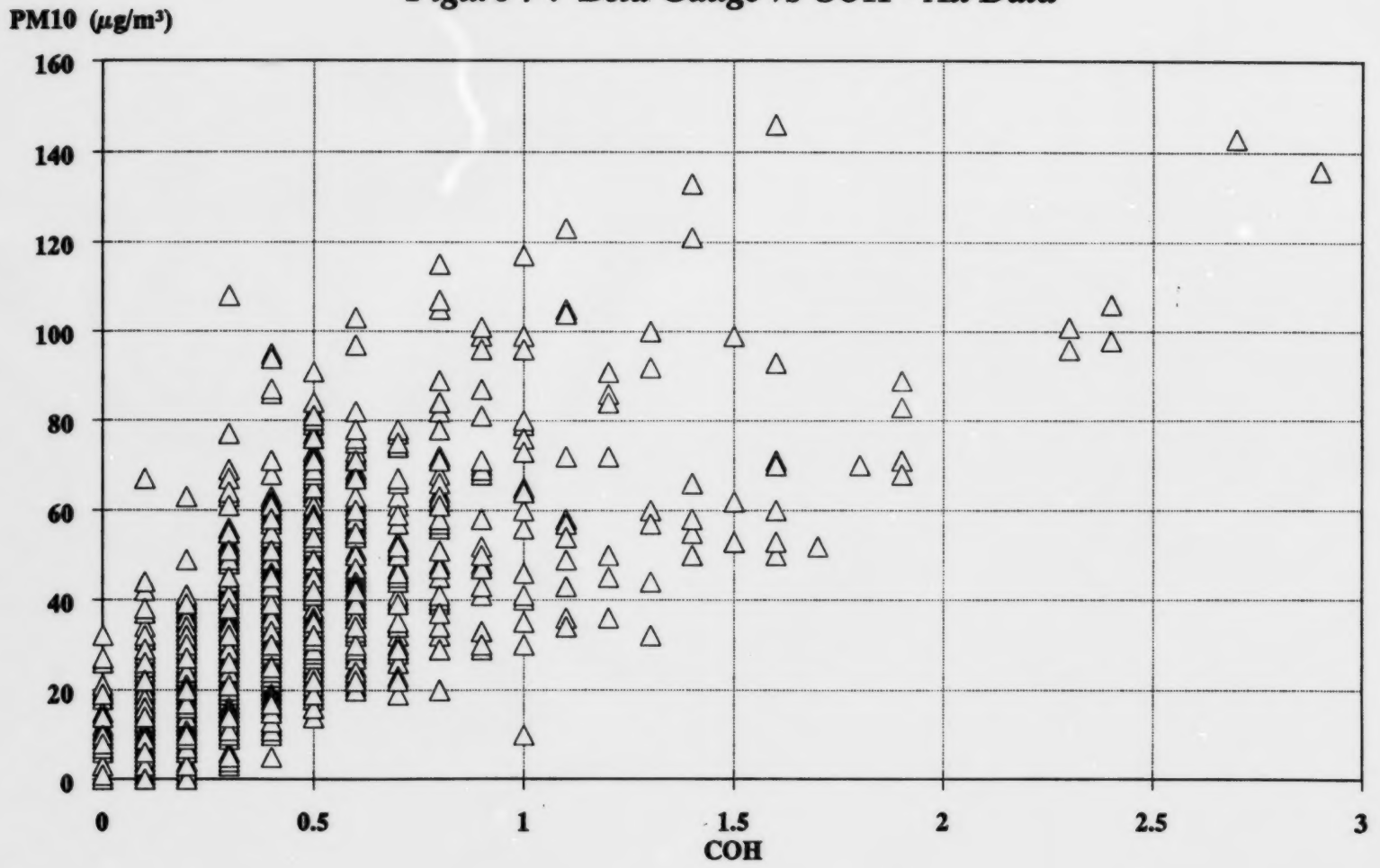


Figure 7 : Beta Gauge vs COH - All Data



4. CONCLUSIONS

The BAM-102 is a well-designed and easy to operate monitoring instrument and appears well-suited for unattended operation in a typical ambient air monitoring location. Although it wasn't evaluated, the telemetry interface appears flexible enough for integration into most provincial real time monitoring networks. No operational problems were experienced with the unit during its four month evaluation period.

Simultaneous 24h PM_{10} concentration data obtained with the BAM-102 and manual samplers (dichotomous sampler and size selective hi-vol) were highly correlated although the BAM-102 produced values somewhat higher than the manual samplers. The BAM-102 potentially can provide much more information on PM10 concentrations, including diurnal profiles and short term episodic concentrations and could serve as a real time PM_{10} monitoring instrument for purposes of index reporting.

Although the coefficient of haze (COH) measurements made at Ottawa were well correlated with BAM-102 PM_{10} concentrations, the slope of the equation relating PM_{10} and COH varied greatly from month to month. Since COH is not a mass based measurement, it is not recommended that COH be used as a surrogate for PM_{10} for daily index reporting.

Further evaluation of the BAM-102 should be carried out, preferably during the summer months at a site impacted by high concentrations of secondary aerosols.